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Intraoperative High-flow Antegrade Irrigation

A New Bowel-cleansing System

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A new intraoperative method, employing a specially designed apparatus, is described by which the colon can be cleansed to a degree not obtainable by other methods. The method enables continuous antegrade irrigation with large volumes of irrigant at high rates of flow, prior to enterotomy. It has been tested in an experimental canine model and found to be safe and effective. [Key words: Bowel preparation; Colonic irrigation]

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THE IMPORTANCE OF A CLEAN COLON to the success of colonic surgery has been well established. Several studies clearly show the importance of mechanical cleansing of the bowel,[1-3] and numerous studies document the benefit of antimicrobial prophylaxis to diminish the viable endogenous intestinal bacteria that contaminate the operative field during the surgical procedure and give rise to septic complications. Despite the many methods of bowel cleansing, however, no preoperative method can reliably eliminate all feces, or reduce the bacterial concentration below 10^5 bacteria per ml of colonic contents.[4-6] Colonic surgery, therefore, is still plagued with septic complications. Wound or intra-abdominal infection, or both, occur in 5 to 15 percent of patients.

We have developed an apparatus and method for intraoperative bowel preparation that we believe can cleanse even a loaded colon to a degree not achievable by other methods. The apparatus (Fig. 1) consists of specially designed irrigating instruments and a mobile unit containing irrigant storage reservoirs, a variable speed peristaltic pump that can be regulated by means of a foot switch potentiometer, and collection containers that can be connected to a suction regulator and vacuum supply.

The specially designed irrigating instruments include a colonic tube and a balloon-tipped rectal tube with a wide diameter lumen through which the colonic tube can be passed (Fig. 2). The colonic tube connects to the tubing from the reservoirs that passes through the pump, and a side arm of the rectal tube is connected to the collection containers by a large diameter flexible hose.

The rectal tube is inserted prior to surgical draping with the aid of a removable obturator. During laparotomy, the colonic tube is passed to the most proximal part of the bowel to be irrigated, the system is sealed, and an intestinal occluding clamp is placed on the bowel just proximal to the tip of the colonic tube (Fig. 3). The bowel can now be cleansed, prior to violation of the bowel wall, by continuous antegrade irrigation with large volumes of irrigant, at high rates of flow.

We have tested this method for efficacy and safety in a canine model.

Materials and Methods

All irrigations were performed on female mongrel dogs weighing between 23 and 35 kg. Preoperative bowel preparation consisted of one day of water only: no laxatives, enemas, or antibiotics were administered. All dogs were anesthetized with pentobarbital and monitored with an esophageal temperature probe and an arterial catheter placed via a femoral artery cutdown. All blood work was drawn from the femoral vein.

Six dogs were irrigated with 20 liters of saline. The saline was made by adding 180 gm of table salt directly to 20 liters of tap water at 37 to 42° C.

Two dogs were irrigated with 15 liters of saline followed by 3 liters of 0.2 percent Clorpactin® WCS-90 in tap water, followed by 5 liters of saline.

One dog was irrigated with 15 liters of saline followed by 3 liters of 0.4 percent Clorpactin in saline, followed by 5 liters of saline.

Physiologic and Histologic Studies: A continuous recording of the arterial pressure wave was made in eight of the dogs and pulse rate and blood pressure were analyzed at 2-minute intervals.

In eight dogs, esophageal temperatures were recorded immediately before and after irrigation.

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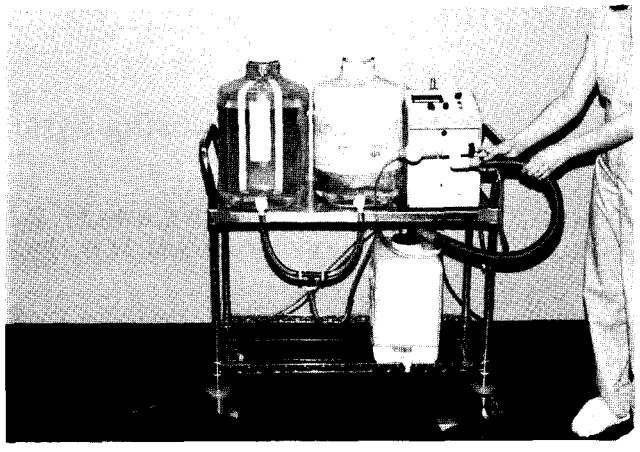

FIG. 1. The mobile irrigation apparatus.

In eight dogs, both infused irrigant volume and effluent volume were measured in a calibrated cylinder. The difference between volumes represented the volume lost during irrigation and was considered to be the maximum amount of fluid the dog might have absorbed.

In eight dogs, blood samples for hematocrit were obtained immediately before and after irrigation.

In nine dogs, blood samples were drawn for serum Na, Cl, K, and BUN concentrations immediately before and after irrigation.

In two dogs irrigated wtih saline only, NA and Cl concentrations were measured in the irrigant and effluent.

In nine dogs, a short segment of colon was excised after irrigation, placed in 10 percent buffered formalin and sent for microscopic examination.

Microbiologic Studies: In six dogs, two sets of blood cultures (two aerobic and two anaerobic) were obtained prior to irrigation, and two sets were obtained after irrigation, before the bowel was incised. Blood cultures were read on the Bactec Blood Culture System at 24 hours, five days, and seven days.

In the five dogs irrigated with saline alone, 10 ml of fluid were aspirated from the colon with a sterile syringe and a 19-gage needle at the beginning of irrigation and

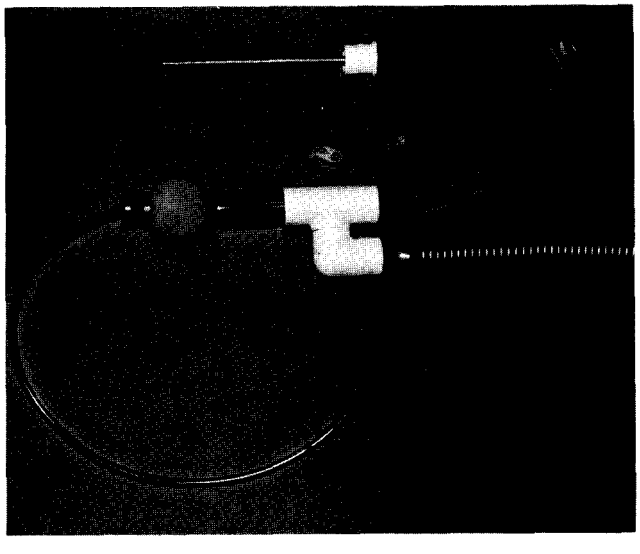

FIG. 2. The colonic tube and rectal tube irrigating instruments.

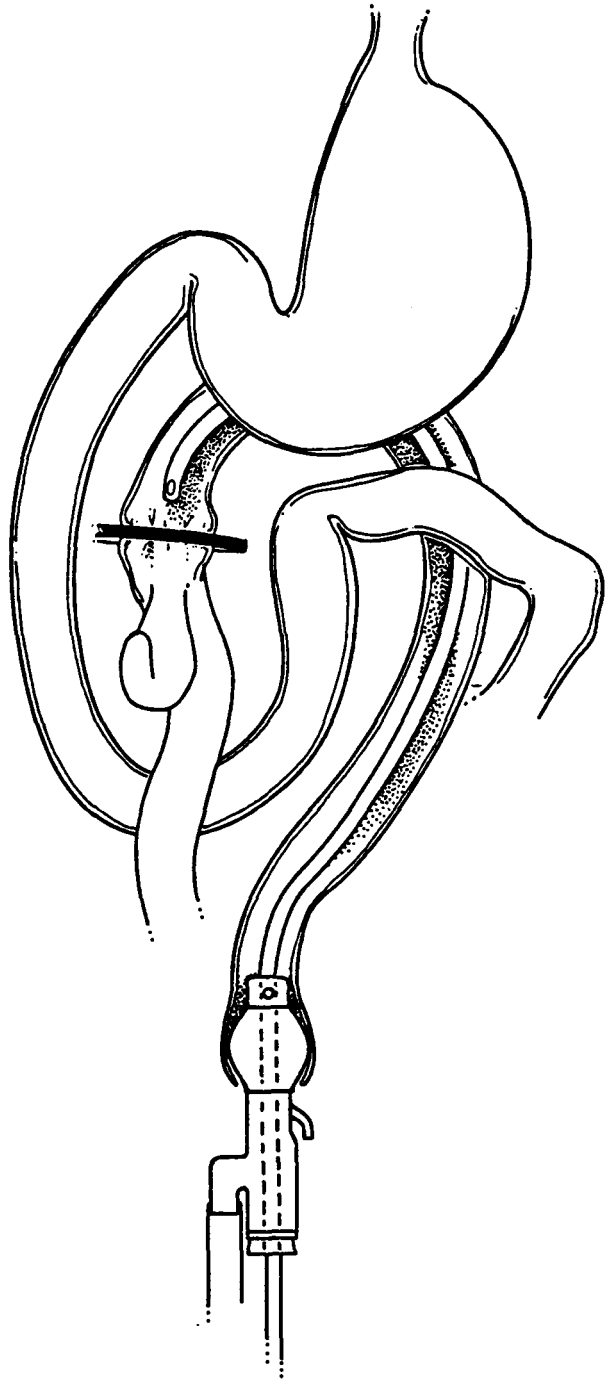

FIG. 3. The method used for intraoperative colonic cleansing in the experimental canine model.

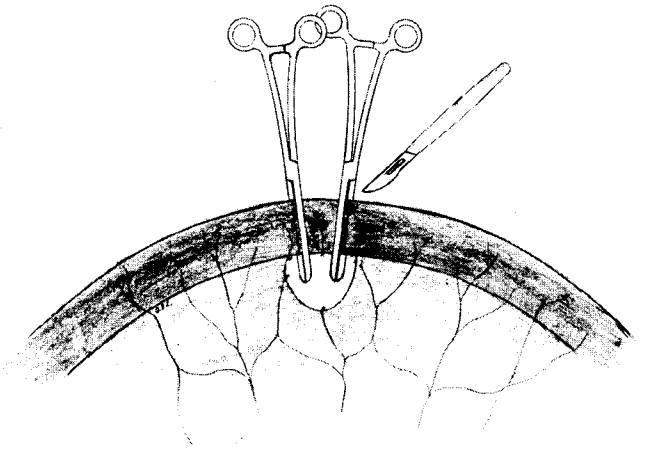

FIG. 4. Excision of colon segment for homogenation and quantitative culture.

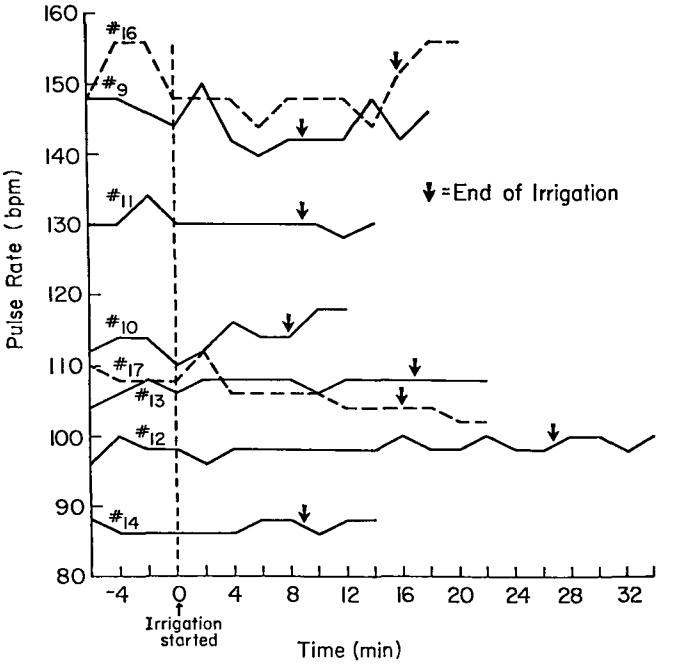

FIG. 5. Effect of irrigation on pulse rate.

then after every 5 liters of saline infused. Air was immediately expelled from the syringe and the needle was capped with a rubber stopper. The bowel was gently massaged before each aspiration. After irrigation was completed, Kocher clamps were placed one inch apart on the colon. The bowel was then divided proximal and distal to the clamped segment (Fig. 4).

In the dog irrigated with 15 liters of saline followed by a 4-minute exposure to 3 liters of 0.4 percent Clorpactin, followed by 5 liters of saline, 10 ml of fluid were aspirated from the bowel at the onset of irrigation, and after 5, 10, and 15 liters of saline were infused. The final aspirate was drawn only after the Clorpactin was washed out with 5 liters of saline. After irrigation, a one-inch segment of colon was excised in the manner described above.

After the final aspirations, all aspirates were immediately sent for quantitative culture. After excision, the clamped bowel segments were weighed in a sterile container and immediately sent for homogenization and quantitative culture.

The bowel aspirates were serially diluted ten-fold in sterile physiologic saline to dilutions of 10^6; 0.1 ml of each

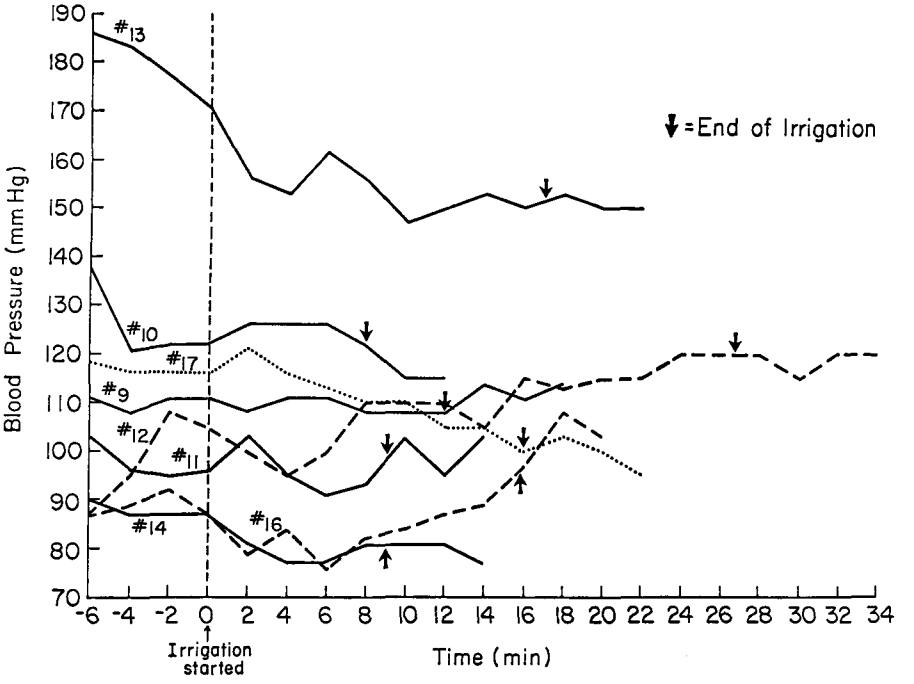

FIG. 6. Effect of irrigation on blood pressure.

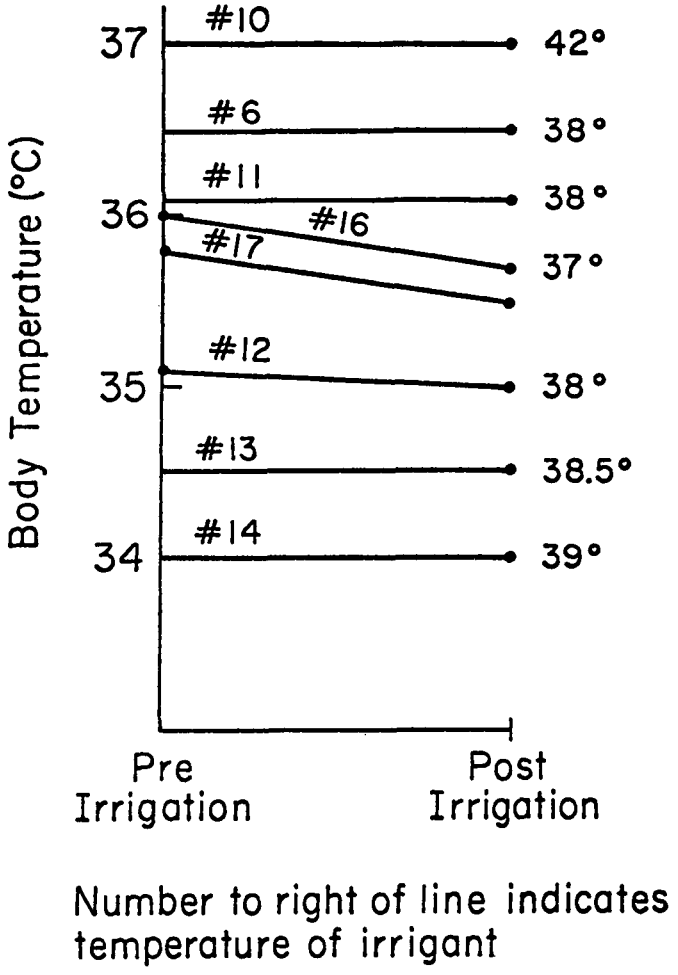

FIG. 7. Comparison between body temperatures before and after irrigation. (Number to right of line indicates temperature of irrigant.)

dilution was immediately plated onto McConkey agar (incubated at 37° C), CNA agar (incubated at 37° C with CO_2), and blood agar (incubated anaerobically at 37° C). All plates were incubated within 1 hour and 15 minutes of original collection. Anaerobic conditions, using internal anaerobic indicators, were maintained by the Gas-pak® system (BBL Becton Dickinson and Company).

Simultaneously, the tissue sample (of known weight) was homogenized for approximately 5 minutes with a sterile solution of 5 percent trypsin to yield a concentration of 0.5 gm/ml. The tissue solution was then serially diluted ten-fold up to 10^5. One tenth of a milliliter of each solution was immediately plated onto McConkey (37° C), CNA (37° C with CO_2), and blood agar (37° C, anaerobically). Anaerobic conditions were maintained in the same manner as the aspirates. All plates were incubated within 50 minutes of excision of the specimen.

Plates were read at two, five, and seven days of incubation. Colony counts for gram-positive, gram-negative, and anaerobic organisms were recorded for each dilution.

Results

High-flow intraoperative irrigation did not have significant effects on hemodynamics or body temperature. Figures 5 and 6 show the pulse and blood pressure trends from 6 minutes before to 6 to 8 minutes after irrigation in eight dogs. Figure 7 compares body temperature before and after irrigation.

Figure 8 shows the volume of irrigant that was not recovered after irrigation in eight dogs. This volume (infused irrigant volume minus effluent volume) represents the maximum amount of irrigant the dogs could have absorbed from the 20 to 23 liters infused. This volume never exceeded 250 ml and averaged 2.3 ml/kg body weight. The small quantity of fluid accidentally spilled during irrigation in some of the early trials was estimated and added to the measured effluent volume. The fact that the unrecovered volume was greater in the

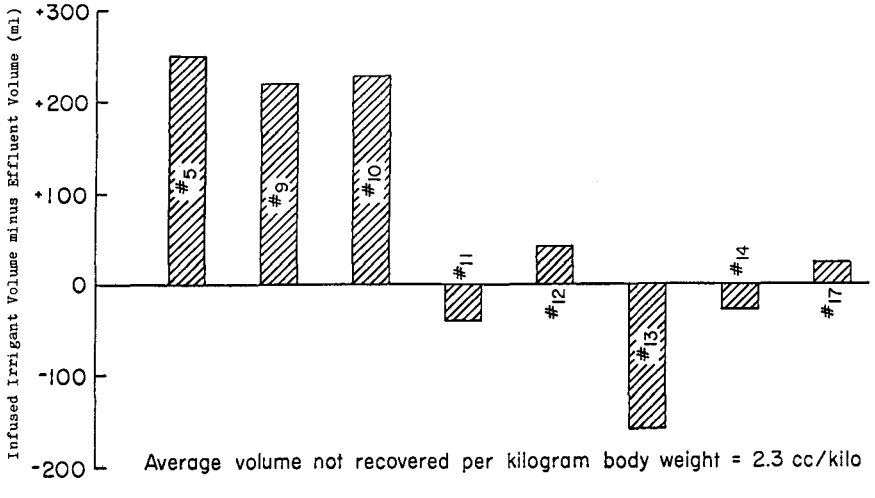

FIG. 8. Volume of irrigant not recovered after irrigation.

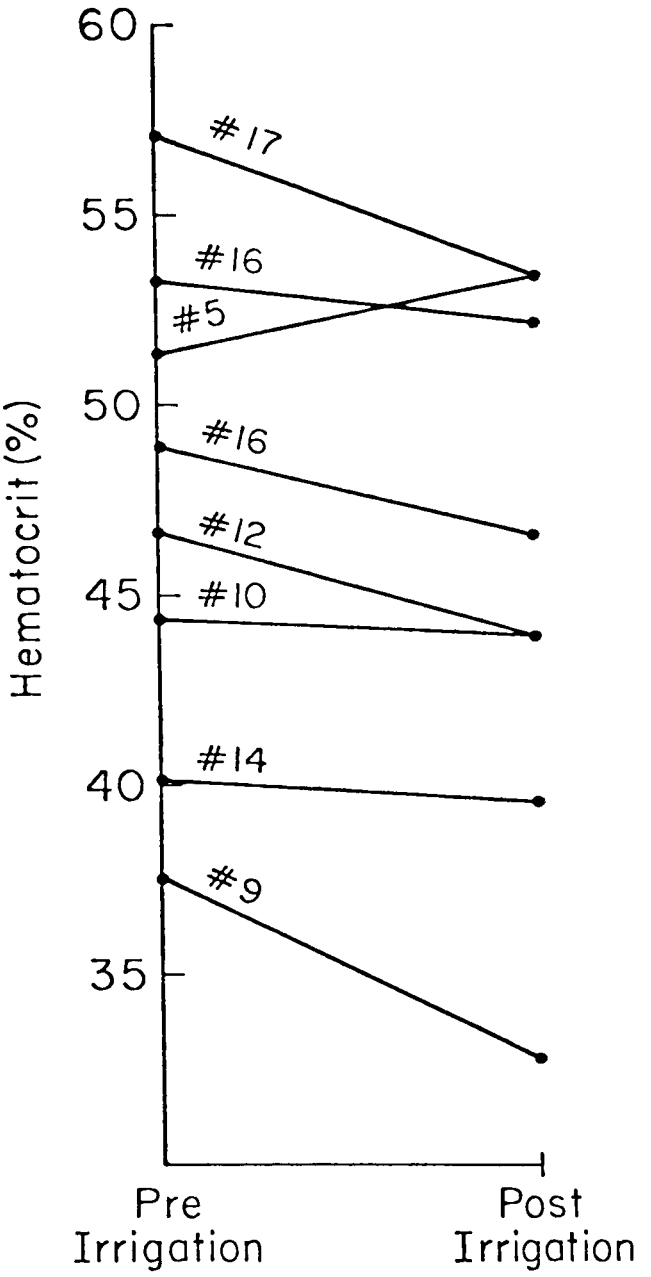

FIG. 9. Comparisons between hematocrits before and after irrigation.

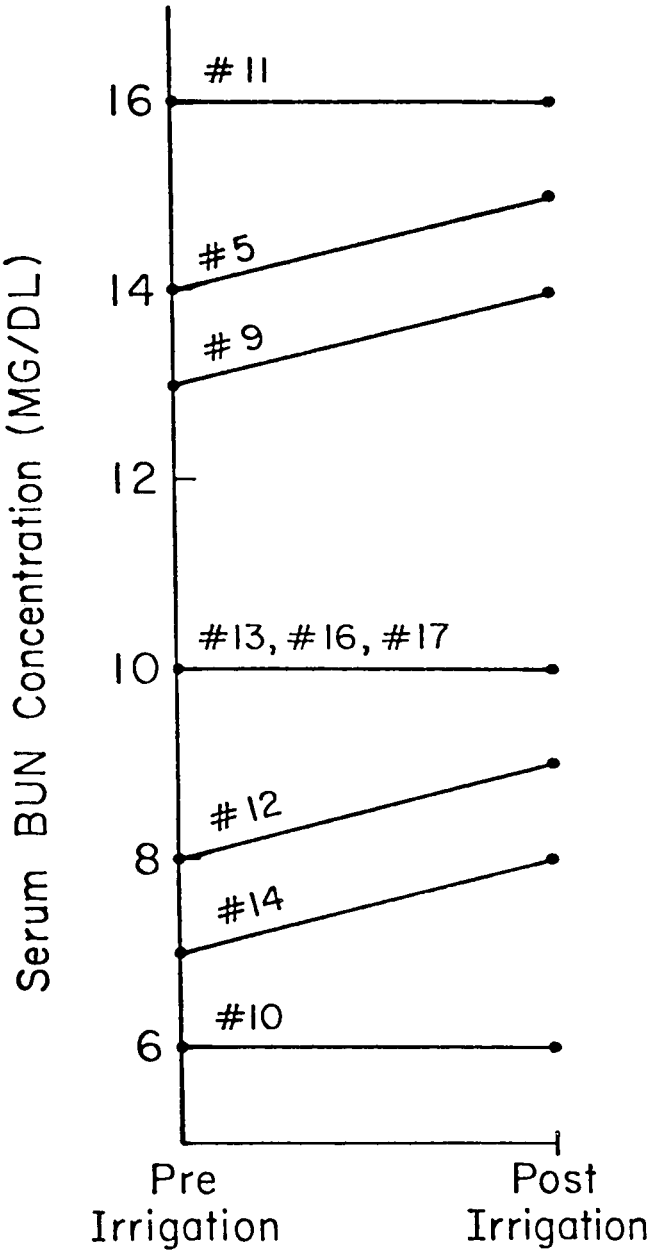

FIG. 10. Comparisons between serum BUN concentrations before and after irrigation.

initial three dogs than in the succeeding trials probably reflects an underestimation of fluid spilled. The fact that more fluid was recovered than was infused in trials 11, 13, and 14 can be explained by the addition of the large fecal volume to the effluent.

The fact that neither the hematocrit (Fig. 9) nor the BUN (Fig. 10) decreased during irrigation also shows that there was no significant fluid absorption.

Analysis of electrolyte concentrations in the irrigant and effluent (Fig. 11) demonstrates that there was also no significant net absorption or loss of sodium or chloride. This is confirmed by comparison between pre- and post-irrigation serum Na and Cl levels (Figs. 12 and 13). There was, in addition, no significant change in serum K concentration as a result of irrigation (Fig. 14).

Microscopic examination of excised segments from nine irrigated colons showed intact mucosa in all specimens. Three specimens showed mild hyperemia, one of which showed subserosal inflammation with polys and eosinophils (No. 11). All other specimens showed no abnormal features.

Results of blood cultures indicate that it is unlikely that

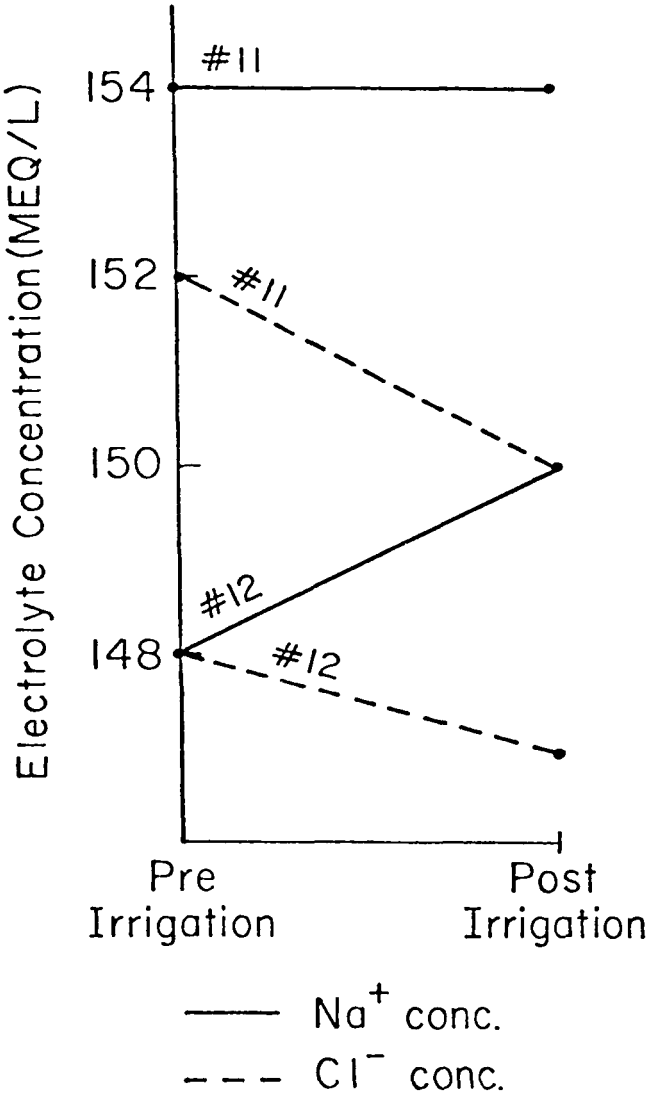

FIG. 11. Comparisons between electrolyte concentrations in the irrigant before and after irrigation.

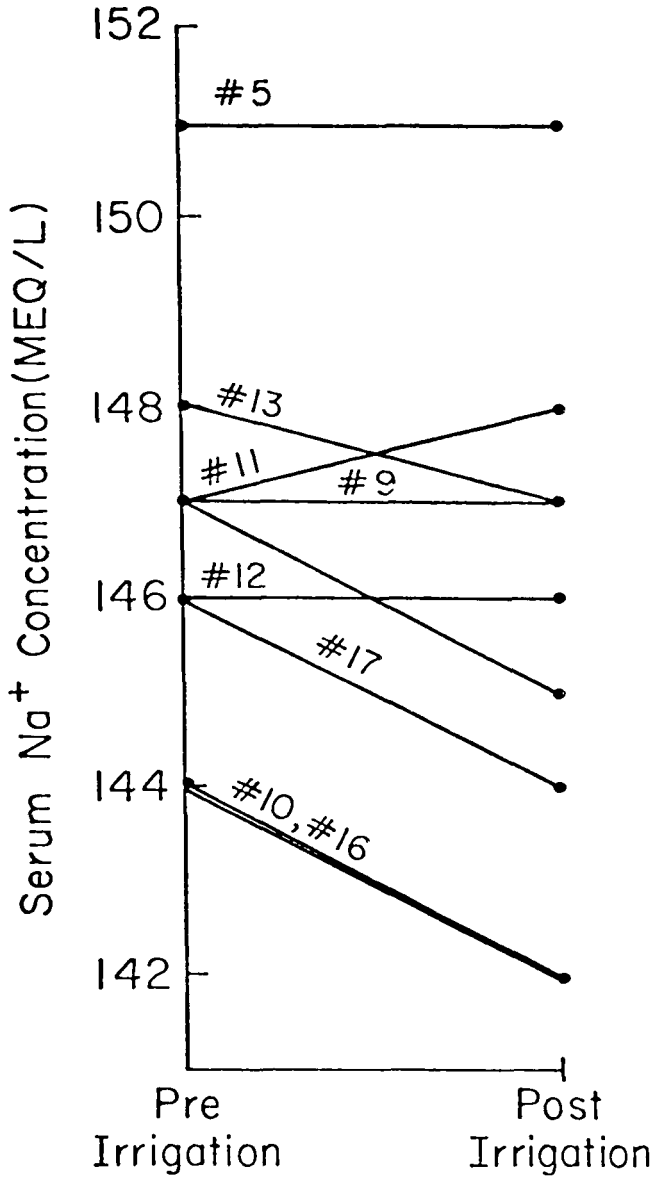

FIG. 12. Comparisons between serum sodium concentrations before and after irrigation.

high-flow irrigation will generate bacteremias. In five of the six dogs tested, both sets of postirrigation blood cultures were negative. In one dog, two postirrigation anaerobic bottles and one aerobic bottle had no growth, while one aerobic bottle grew *Staphylococcus epidermidis*, which is presumed to have been a skin contaminant. All preirrigation cultures were negative.

In most cases, a colon loaded with feces was encountered at surgery. A loaded colon increased irrigation time considerably yet, despite this, all irrigations were completed in less than one-half hour. When hard feces was encountered, the bowel would be filled with irrigant through the rectal tube, which would soften the stool and evacuate much of it in the manner of an intraoperative enema. The wide diameter of the rectal tube here was a distinct advantage. The colonic tube could then be passed through the rectal tube and bowel expeditiously.

Irrigation with saline alone achieved an excellent bowel preparation. No residual feces could be seen when the lumen was examined at surgery. Usually, after 5 liters of irrigation and, invariably, after 10 liters, the effluent appeared clear. However, as seen in Figure 15, as many as 10^6 bacteria per ml could be cultured even after 10 liters of irrigation when the aspirate appeared clear. Figure 15 shows the decline in bacteria counts in the colons of five separate dogs irrigated with 20 liters of saline each.

Lower bacteria counts were achieved when an antiseptic (Clorpactin WCS-90) was used in conjunction with

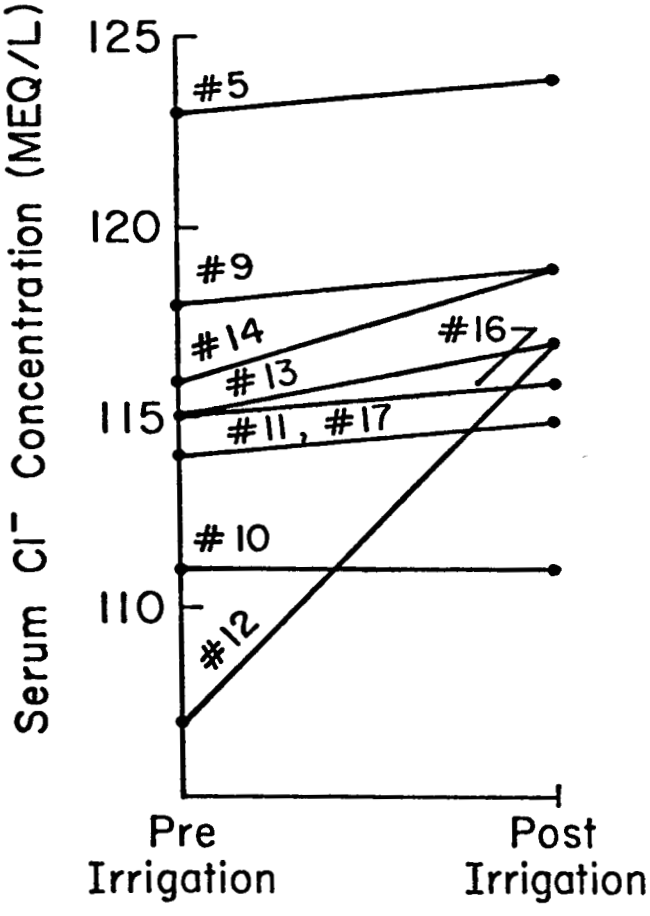

FIG. 13. Comparisons between serum chloride concentrations before and after irrigation.

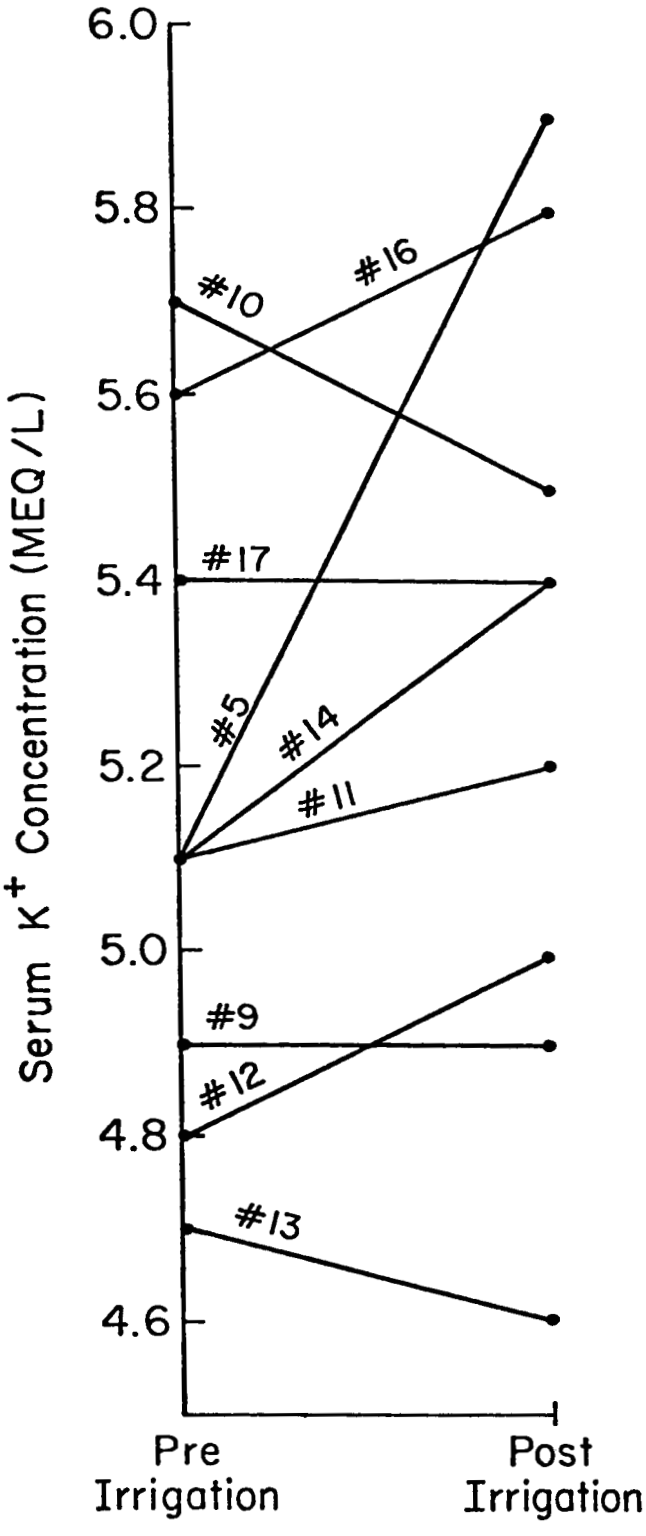

FIG. 14. Comparisons between serum potassium concentrations before and after irrigation.

saline. Figure 16 shows the decline in bacteria counts when colonic irrigation with 15 liters of saline followed by a 4-minute exposure to 3 liters of antiseptic, followed by 5 liters of saline, was performed. No organisms could be cultured from the bowel aspirate at the end of irrigation.

Table 1 shows the bacterial concentrations of homogenized segments of bowel from a control trial wherein the dog was prepared preoperatively in an identical manner but the colon was not irrigated, from each of five saline trials, and from the trial in which saline plus 0.4 percent Clorpactin was used.

All seven dogs not sacrificed at surgery were tolerating a solid diet by the second postoperative day. The average number of days until the first postoperative bowel movement was 3.3.

Discussion

A great deal of controversy exists in regard to the ideal method of bowel preparation for patients who undergo surgery of the colon, and multiple regimens of mechanical and antimicrobial preparations have been designed to

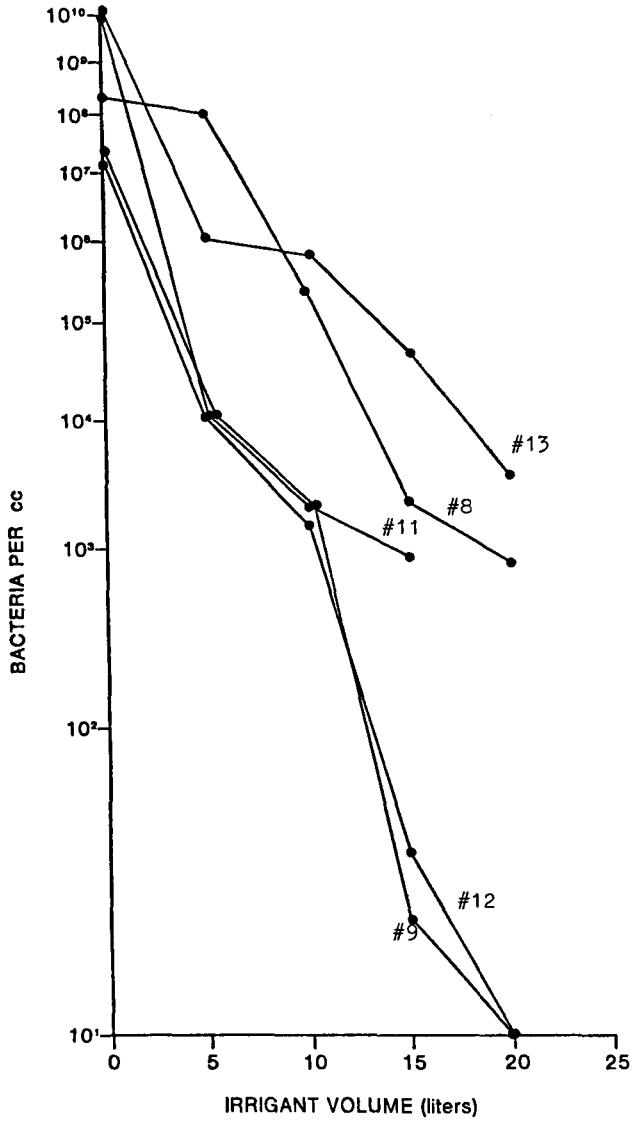

FIG. 15. The decline in bacteria counts during saline irrigation.

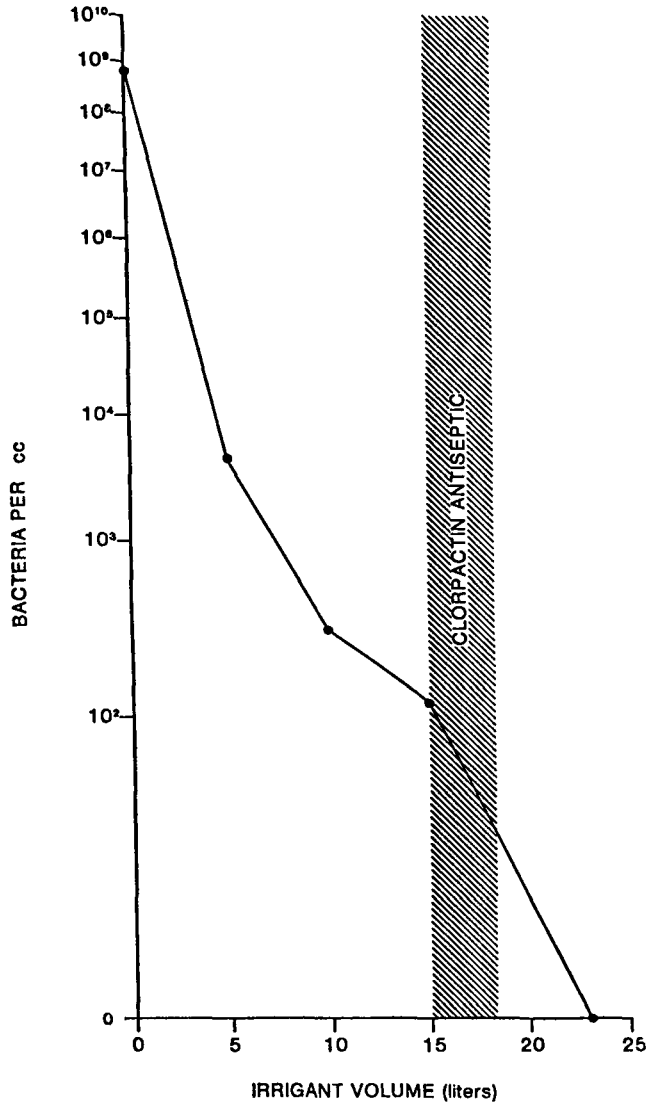

FIG. 16. The decline in bacteria counts during irrigation with saline and antiseptic (trial no. 17).

reduce the concentration of colonic bacteria below critical levels.

The most widely used method of preparing the colon for surgery consists of dietary restriction to clear fluids, laxatives, enemas, and one of multiple antibiotic combinations administered orally on the day prior to surgery. This method has many disadvantages. It achieves suboptimal cleansing[7] and must be restricted to elective cases. Administration is highly variable, and is distressing to the patient. It prolongs hospital confinement and causes

TABLE 1. *Microbiology of Colon Obtained after Irrigation*

Trial No.	Irrigant	Bacterial Concentration*	Percent Anaerobes	Percent Aerobes	Percent Gram Negs
15	No Irrigation Control	1.4×10^8	81.5	18.4	0.06
8	Saline	2.8×10^5	47.4	50.6	2.0
9	Saline	1.5×10^3	77.1	9.6	1.3
11	Saline	1.5×10^4	87.2	12.7	0.1
12	Saline	1.9×10^7	99.97	.03	—
13	Saline	6.2×10^5	92.4	0.8	0.1
17	Saline + 0.4% Clorpactin	6.9×10^3	67.4	31	1.6

*Concentration expressed as colony-forming units per gram of colonic tissue.

nutritional deprivation. It promotes the development of antibiotic resistant intestinal flora and has adverse metabolic effects. The antibiotics employed can be toxic. Preparing the patient requires a significant labor investment by hospital staff, and can be wasteful and even harmful should surgery be canceled or postponed. Furthermore, preparing a patient for colonic surgery in the conventional manner entails considerable expense.

An alternative method of bowel preparation, whole-gut irrigation,[8] and variations utilizing mannitol[9] or "Golytely,"[10] avoid some of the disadvantages of conventional bowel cleansing techniques. These procedures may shorten hospitalization but they also have serious disadvantages. Cleansing is still suboptimal,[6,11] fluid overload and electrolyte imbalance may occur,[12] the technique may be distressing to patients, causing nausea and vomiting on occasion,[13] and also requires a substantial labor investment by the ward nurse.

A large percentage of patients prepared for elective colonic surgery by any of these methods is found at laparotomy to have a fair degree of fecal loading and patients operated on under emergency conditions invariably have unclean bowels. To deal with a bowel loaded with feces encountered at surgery, several methods of intraoperative bowel preparation have been devised. Poth,[14] Jones *et al.*,[15] and Arango *et al.*,[16] have described and advocated the instillation of antimicrobial agents into the bowel lumen prior to enterotomy. These methods fail to remove the fecal matter, which cannot be completely sterilized. When the bowel is incised or opened, virulent material can still escape, infect the parietes, and soil and obscure the anastomotic field.

Muir[17] and Dudley *et al.*[18] describe intraoperative irrigating techniques. These techniques, however, are clumsy, may easily result in spillage of bowel contents, leave significant amounts of fecal matter in the bowel, and do not affect the concentration of bacteria within the remaining feces. Other intraoperative irrigating techniques, such as those described by Alexander[19] and Thow,[20] amount to little more than intraoperative enemas. Such methods, in a repeating sequence, force fluid through the bowel in a retrograde direction, and rely on peristalsis to flush out the irrigant and colonic waste. This bidirectional flow, by washing contaminants back and forth within the bowel, makes the process slow and inefficient, and limits the degree to which the bowel can be cleansed.

Gliedman *et al.*[21] combined both irrigation and antimicrobials, but used no more than 2000 ml of irrigant in their experiments on dogs and it took at least 5 minutes for 1000 ml to traverse the colon.

Whenever unidirectional antegrade irrigation was employed by any of these authors, an enterotomy for placement of a proximal irrigating catheter or large bore needle puncture of the bowel was performed, exposing the operative field to a risk of contamination even before cleansing was begun.

The method described herein can achieve higher degrees of cleanliness than can other methods. Whereas preoperative preparation by any known method cannot reliably reduce the total bacterial concentration of colonic contents below 10^5 bacteria per ml, we have shown that this intraoperative method can eliminate all feces and produce near sterile conditions. The consistency with which this can be achieved must be determined by further studies and the clinical application of this procedure must be investigated. In the experimental setting, the method is shown to be fast, safe, and effective. The use of a colonic tube and pump, a wide diameter rectal tube to reduce outflow resistance, and application of suction, together enable high-flow unidirectional irrigation. Fluid absorption and electrolyte flux are negligible because only the lower bowel is irrigated and exposure time is short. It is anticipated that this method will suffer none of the stated disadvantages of either conventional bowel preparation techniques or whole-gut irrigation. The method may be applicable to many emergency situations, as well as to routine elective patients, and should result in the ability to establish an "elective environment" at non-elective times.

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